Methodology Guide
Biodiversity Footprinting for Financials

BFFI Method

PRé
Fact-based sustainability

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About PRé

For more than thirty years PRé has been at the forefront of life cycle thinking and has built on its knowledge and experience in sustainability metrics and impact assessments to provide state of the art methods, consulting services and software tools. Internationally, leading organizations work with PRé to integrate sustainability into their product development procedures in order to create business growth and business value. PRé has an office in the Netherlands and a global partner network to support large international or multi-client projects.

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Table of contents

1 Introduction

The backbone of healthy ecosystems is biodiversity, the variety of all living things on the planet. Biodiversity is defined as "the variety of animals, plants, fungi, and even microorganism like bacteria that make up our natural world"[1]. The interplay of those species and organisms form ecosystems, that maintain the natural balance, and ultimately supports life on earth.

Unfortunately, human activity has a strong negative effect on biodiversity, which leads to its decline at an alarming rate. Since 1970, populations of mammals, bird, fish, reptiles and amphibians have dropped on average by 68%[2]. Latin America and the Caribbean, with their sensitive tropical regions, have seen a particularly rapid decline in biodiversity (around 94%). Much of this loss is caused by habitat destruction due to farming and logging. The rising impacts of climate change pose an additional major threat due to warming temperatures, rising sea levels, resulting habitat loss, invasive species and more, causing a self-reinforcing vicious cycle for biodiversity. To help halt the loss of biodiversity, it's crucial for humanity to make decisions with biodiversity in mind.

The financial sector is playing a crucial role in today's societies for the allocation of resources. Ultimately, the financial sector decides where money is flowing – which corporations and activities receive funding, and which do not. Therefore, it is essential to bring biodiversity into the financial equation. Taking biodiversity-related risks and opportunities into account is crucial to make future-proof investments, reduce the risk of sunk costs, and ultimately maintain a world that can be invested in in the future. Research has shown that "biodiversity is as essential to our economy and financial system as climate, and the problem of losing nature is at least as acute as climate change, if not more so"[3].

Assessing and quantifying the impacts of financial products and economic activities on biodiversity is receiving ever more attention on global stage. The increasing regulatory pressure of the European Grean Deal, such as through the EU Taxonomy[4], makes the protection and restoration of biodiversity and ecosystems a cornerstone of green finance. Incorporating biodiversity into financial decision making is therefore not a choice anymore – it is becoming a necessity.

Unfortunately, assessing the impacts on biodiversity is far from a trivial thing, even when you are in a specific location and have time to study an area. One of the problems is that there are many levels at which you can describe biodiversity:

- The species abundance or diversity,
- The gene pool, the variety of genes, and with that the robustness of the system,
- The habitat,
- The functional value of the ecosystem (what is the economic value it generates),
- Etc.

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[1] https://www.worldwildlife.org/pages/what-is-biodiversity
[2] https://www.worldwildlife.org/magazine/issues/summer-2021/articles/a-warning-sign-where-biodiversity-loss-is-happening-around-the-world
[3] From Paris to Kunming: Enabling a carbon net zero and nature-positive financial sector, Sustainable Finance Lab (2022)
[4] https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en

The complexity of the task requires an understanding of how investments influence economic activities, and from there how such changes disturb habitats and cause a loss (or gain) in species numbers. Life cycle assessment (LCA) methodology has been designed to model environmental impacts caused by the production of products and can be used to assess the environmental impact of financial products and activities on biodiversity. The Biodiversity Footprint for Financial Institutions (BFFI) is a method grounded in LCA, which allows to quantify the biodiversity impacts of economic activities, companies, and entire financial portfolios. This document is providing methodological guidance on the theory of the BFFI, its practical application, and aims at further guiding results interpretation. Chapter 2 explains the background of biodiversity footprinting. Chapter 3 present the methodological approach of the BFFI and specific calculation approaches for various asset classes. Chapter 4 captures developments and ambitions of the BFFI. This chapter also covers important references, reviews, and recognition form stakeholders.

2 Biodiversity Footprinting

2.1.1 Conducting a biodiversity footprint

Impacts on biodiversity can be measured and expressed as a biodiversity ‘footprint’. With an annual biodiversity footprint analysis, financial institutions can monitor changes in impacts on biodiversity through time. This assessment is based on the contribution of an economic activity to drivers of biodiversity loss or gain, like land use and land transformation or climate change. In the case of a biodiversity footprint for financial institutions, the footprint may focus on the impact of the financial institution itself (for example impacts resulting from land use and energy use by a financial institution’s buildings) as well as the impact of the economic activities in which financial institutions invest. However, the impact of land use and energy use of financial institutions’ offices will be negligible compared that of the economic activities supported by the loans and investments. For this reason, the biodiversity footprint for financials focuses on the biodiversity impact caused by loans and investments. Financial institutions can use the information in a biodiversity footprint to assess what steps are needed to avoid or minimize negative impacts and optimize avoided or positive impacts. The results can be applied to monitor the progress towards a no net loss of biodiversity or a net positive contribution. It can further be used to guide financial decision making, and steer entire portfolios to take the reduction of biodiversity impacts into consideration.

Species richness is often used as an indication of the health of an ecosystem and the damage to diversity can then be described as the fraction of species that has been lost in comparison with a natural or undisturbed area. This measure also has its problems, as sometimes the species numbers increase while we may not agree that these are desired species. The opposite is also true. While the species diversity is high, we may also see a decline in population numbers.

A biodiversity footprint is in many ways similar to a carbon footprint. Both footprints look at the impact resulting from environmental pressures caused by economic activities. However, in a biodiversity footprint, more environmental pressures are included, like land use and water use, than in a carbon footprint, which only focuses on greenhouse gas emissions. A biodiversity footprint therefore takes into account a broader set of environmental impacts, compared to a carbon footprint.

There are more significant differences:

1. It is relatively clear what should be measured when looking at climate change. The IPCC agreed on measuring Global Warming Potential expressed in CO_2-equivalents. For biodiversity however, there is no agreed metric yet; one could measure species richness or species abundance, but there are more ways of quantifying biodiversity impact.
2. Greenhouse gas emissions have a global impact regardless of the location of the emission. The resource use and emissions impacting biodiversity often have a localised effect.
3. Most companies already report on GHG emissions, so data can be found in corporate reports, statistics, and databases. For biodiversity, data is scattered over many sources and important pressures, like eutrophication or ecotoxicity, are difficult to quantify.

Therefore, this biodiversity footprint comes with limitations, and should be interpreted with care.

2.1.2 Use of a biodiversity footprint

Conducting a biodiversity footprint is not an objective in itself. A biodiversity footprint supports a financial institution in its understanding of the relations between its investments and loans and (impacts on) biodiversity. Ideally, the results can steer decision making towards reducing the impact on biodiversity.

To improve the impacts on biodiversity, a financial institution will need to identify ways to minimize negative impacts on biodiversity and ways to contribute to avoided and positive impacts. The so-called 'mitigation hierarchy' can guide the financial institution's decisions in reaching this net gain. The mitigation hierarchy shows that the first step should be to avoid negative impact, followed by minimizing and restoring negative impact, before compensating ('offsetting') any remaining negative impact.

Founded on the mitigation hierarchy, the conservation hierarchy aims to combine efforts to lower existing impact with conservation actions to create positive impact in one single framework.

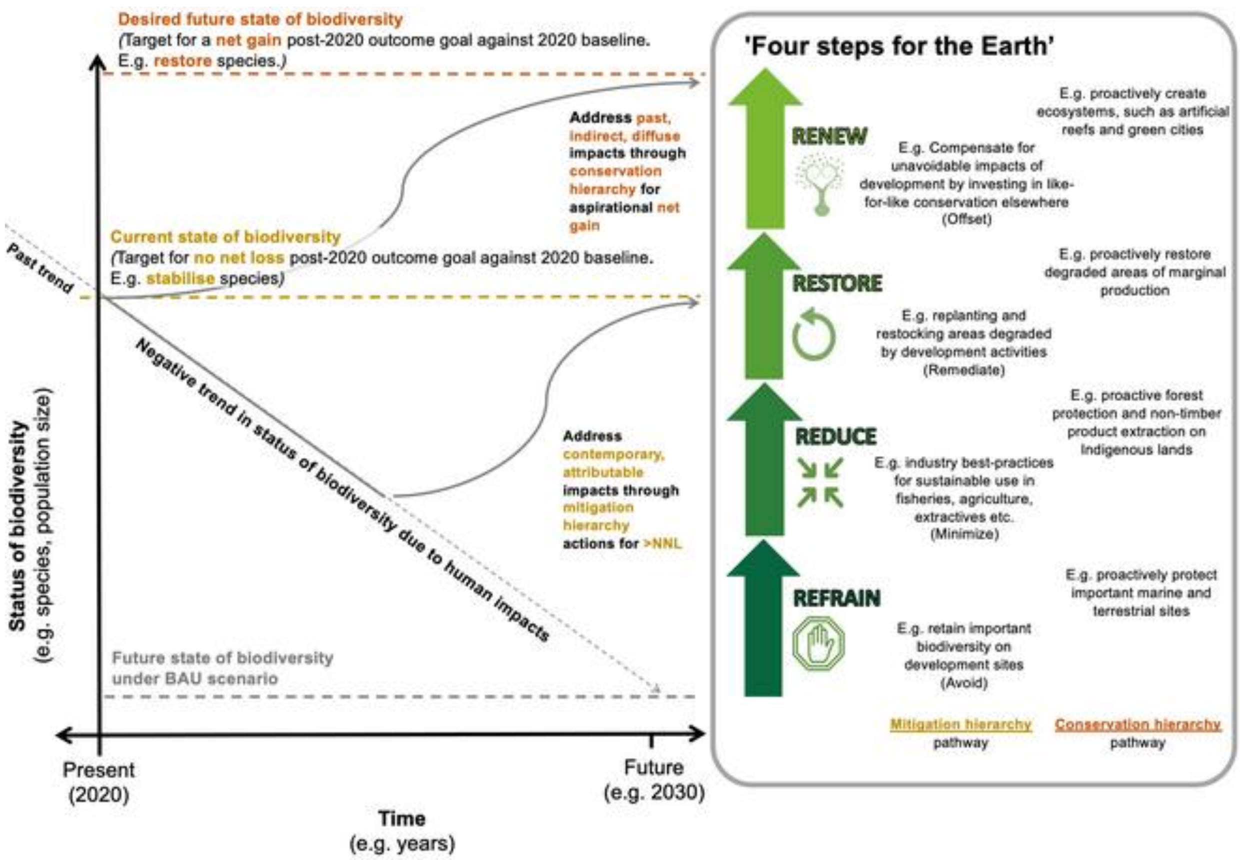

Figure 1. Mitigation & conservation pathways to bend the curve (Source: Conservation Hierarchy)[5]

[5] https://conservationhierarchy.org/what-is-conservation-hierarchy/https://conservationhierarchy.org/what-is-conservation-hierarchy/

Many financial institutions already put investment criteria in place with regards to minimising and reducing impact (e.g. exclusion criteria for polluting industries). For investments in sustainable practises like green energy projects, the concept of avoided impact is used. Avoided impact from green energy projects is calculated by comparing their negative footprint with the counterfactual situation that the same amount of energy would be produced using the (in most cases largely fossil based) existing energy infrastructure.

The discussion on how these avoided impact fit in a no net loss, or net gain objective are ongoing. It, but it is clear however, that actual positive impact, meaning an increase in biodiversity, is needed to bend the curve. An overview of the mitigation and conservation pathways is show in Figure 2.

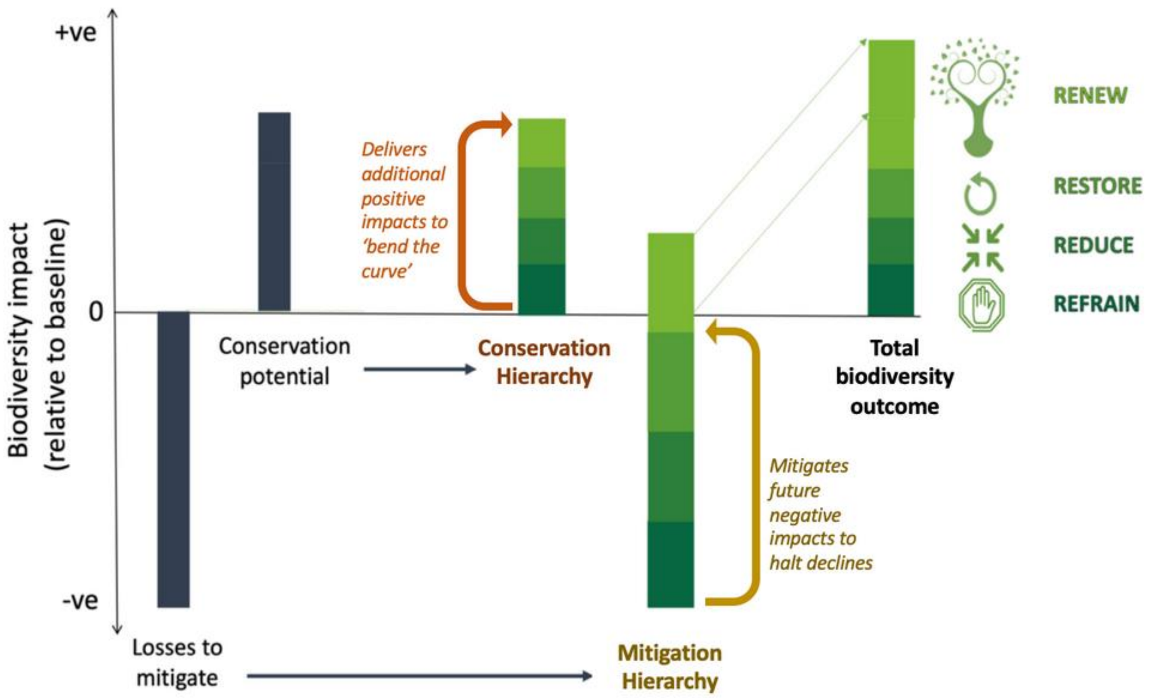

Figure 2: Mitigation & Conservation Hierarchy (Source: Conservation Hierarchy)[6]

[6] https://conservationhierarchy.org/what-is-conservation-hierarchy/ https://conservationhierarchy.org/what-is-conservation-hierarchy/

A biodiversity footprint can be used to:

1. Understand how investments impact biodiversity: what are the impact hotspots and why?
2. Understand what can be done to avoid or minimise negative impacts.
3. Understand how investments can lead to avoided impact negative or even positive impact.

So you can:

1. Develop or fine-tune a biodiversity policy and/or investment criteria.
2. Engage with investees on biodiversity.
3. Use a biodiversity policy to contribute to goals on climate, water and the SDGs.

In order to:

1. Manage and reduce financial risks resulting from biodiversity impacts and dependencies.
2. Show clients and stakeholders how potential biodiversity impact hotspots are managed.
3. Achieve ESG objectives.

2.1.3 Limitations of the footprinting methodology and data

The footprint calculation has its limitations, both from a methodological viewpoint and from a data viewpoint. For example, the introduction of invasive species is considered an important driver of biodiversity loss but cannot be included in footprint calculations yet. Depending on the relevance of this driver in the sectors in which the financial institution invests, the actual footprint could be much higher (more negative).

Moreover, a large part of the footprint calculation is based on 'background data', in many cases country-specific sector average environmental data from databases. This is therefore not the actual environmental data of the full supply chain of an individual company. This also means that best practices of individual companies are often not reflected in the footprint, neither is the result of the investment criteria of a financial institution. Company specific information can be included when available. This includes taking into account investment criteria, like certification requirements, or the use of more specific data. The more specific data is available, the more detailed and insightful the biodiversity footprint will be.

These limitations mean that the interpretation of the footprint result should be done with care and may require 'zooming in', i.e. looking in more detail at the 'impact hotspots'. Biodiversity footprints can be complemented by qualitative analysis to assess the limitations of the footprint methodology used and can enable a correct interpretation of the results. Biodiversity footprints can also be used as a basis for ecosystem dependency analysis or monetization of impacts.

3 The BFFI

3.1 Methodological Approach

The Biodiversity Footprint Financial Institutions (BFFI)[7] was developed by PRé[8] and CREM[9] and ASN Bank[10]. The BFFI is based on a life cycle assessment (LCA) approach and uses an already existing pressure-impact model (ReCiPe)[11] and environmental data from the EXIOBASE[12] database. A first pilot using the BFFI methodology was conducted in 2016, assessing the footprint of ASN Bank's investment portfolio (covering the bank's investments in 2015). Today, the BFFI builds upon:

- The ReCiPe methodology (ReCiPe 2016), which allows for regionalization of impacts in certain impact categories (such was water use, eutrophication, and acidification);
- and the newest version of EXIOBASE (v3.4), which covers 44 countries (contributing to 95% of global GDP), 5 Rest-of-World regions, providing input-output data for 163 industries and their economic activities.

The BFFI methodology is comprised of four major steps, illustrated further in Figure 2:

1. Understanding how an investment facilitates a certain economic activity, that has impacts. For this, the investment data is analysed and often additional data has to be collected from annual reports, statistics etc.
2. The translation of economic activities into the emissions and resource use. For this we use LCA databases. These databases include GHG emissions, emissions of toxic substances, and excess nutrients, as well as the use of land and water resources. In LCA terminology this is referred to as the '*Inventory phase*'.
3. The translation of emissions, land, water and resource use into environmental impact as well as an assessment of how these impacts contribute to biodiversity impacts. In LCA terminology this is referred to as '*Life-Cycle Impact Assessment*'.
4. Interpret the results using both quantitative impact calculations and the qualitative analysis, and take action.

Each step is explained in detail below.

[7] https://pre-sustainability.com/solutions/consulting/sustainable-companies/biodiversity-assessment/
[8] https://pre-sustainability.com/
[9] https://crem.nl/en/home_en/
[10] https://www.asnbank.nl/home.html
[11] https://pre-sustainability.com/articles/recipe/
[12] https://www.exiobase.eu/

Figure 3. Methodological Approach of the BFFI method

Step 1: Understand the investment

In the first step of the analysis, we need to understand the investment, and the economic activities that are linked to a specific investment. Important questions to be answered are (1) what scopes need to be included in the footprint and (2) how a link can be made between a company and the economic activities it is involved in.

A key issue in the BFFI is to avoid overlaps and double counting. For instance, a financial institution invests in businesses related to construction as well as in mortgages. If the impact of building a house would be covered under mortgages, this would lead to a double count: the impact of construction is included twice. Another form of double counting is related to supply chains. In the financial institution's footprint calculations, supply chains of companies invested in (scope 3) can be included in the calculation, even when the financial institution does not invest in companies in these supply chains. If other financial institutions start footprinting as well, significant overlaps can occur when the same companies are included in different footprints.

For all asset classes the 'follow the money' principle is applied when assessing impact. This means that the footprint calculations are based on the economic activities facilitated by the investment. An important question is what parts of the supply chain need to be included to cover the most significant impacts. Since most biodiversity impact takes place at the beginning of the supply chain (primary production), it is essential to include the full scope 3 upstream. Taking scope 3 downstream into account is complex because products can be used in different ways. Therefore, this is still work in progress for most asset classes.

Step 2: Assess environmental inputs and outputs

The LCA community has developed a number of generic databases that list the emissions and resource use for common human activities. There are two basic types:

- The traditional approach. An LCA database that describes each human activity as a process and specifies the inputs and outputs of every process in physical units; for instance, to produce a kg of steel you need x kg of coke and y kg of ore, while you emit z kg of CO_2. Examples of common LCA databases are ecoinvent[13], Agribalyse[14], CarbonMinds[15], and many more.
- The input-output approach. These databases do not describe a specific industrial operation but average the activities in an economic sector, and specify the inputs and outputs in monetary terms. In the same example: to produce one euro worth of steel, you need to purchase x dollar from the fossil fuel sector, and y dollar from the ore sector, while you emit y kg of CO_2. The data are sector averages, mostly based on statistics. One can thus not find data on a specific company as in the traditional LCA databases. For the BFFI, we mainly use EXIOBASE v3.4[16] as the input-output database. More information can be found on www.exiobase.eu. A new feature of this version is that data are not only specified in financial inputs and outputs, but also physical factors are also available. This is helpful when we analyse companies and the products they produce[17].

Both types of data have their advantages and disadvantages: traditional data can be more specific. Using traditional LCA data means that there is no need to work with the average impacts of the fossil fuel sector; instead, data that accurately specifies the impact of a specific supplier can be used. The input output database is rough, but can adequately describe a complete economy, and in our case even contains a full model of the global economy and the impact each sector has. Both types of databases produce a list with hundreds, and sometimes thousands of emissions and resource uses.

We are currently using EXIOBASE v3.4 with the base year 2011. The data is becoming increasingly outdated, and we aim to update to EXIOBASE v4 as soon as it is published. As of this version, the base year is 2016 and the sector granularity in improved to cover 600 sectors.

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[13] https://ecoinvent.org/
[14] https://doc.agribalyse.fr/documentation/
[15] https://www.carbon-minds.com/
[16] https://www.exiobase.eu/
[17] EXIOBASE works with a standard model of the economy; it covers 44 countries, that together represent 90% of the World's economy and 5 "rest of the World" regions that cover the remaining 10% of the economy. It has collected data for all 49 regions on economic activities, environmental and some social aspects. For this, it distinguishes 163 industrial and service sectors. All trade flows between all these sectors are specified, which leads to millions of trade flows. There are also some special categories, like the activities caused by the final consumption in a country and the impacts of government expenditure and purchases.

Step 3: Assess environmental pressures and the impact on biodiversity

Once we have a list of resources and emissions based on the economic activities caused by the investment and the inputs and emissions modelled using EXIOBASE, it is important to understand their environmental impact. Over the years many researchers developed methodologies that translate all these emissions in 10 to 20 so called 'impact categories', such a climate change, land use, water depletion, ozone layer depletion etc. Interpreting such a list of impact categories is not easy, and that is why some of these methods have been further reduced to specify the results at a higher aggregation level. Since 1995, PRé Sustainability has been a strong promoter of this idea, and has been responsible for the development of several methods, such as Eco-indicator 95, Eco indicator 99 and ReCiPe 2008. In the BFFI, we use the latest version ReCiPe 2016[18].

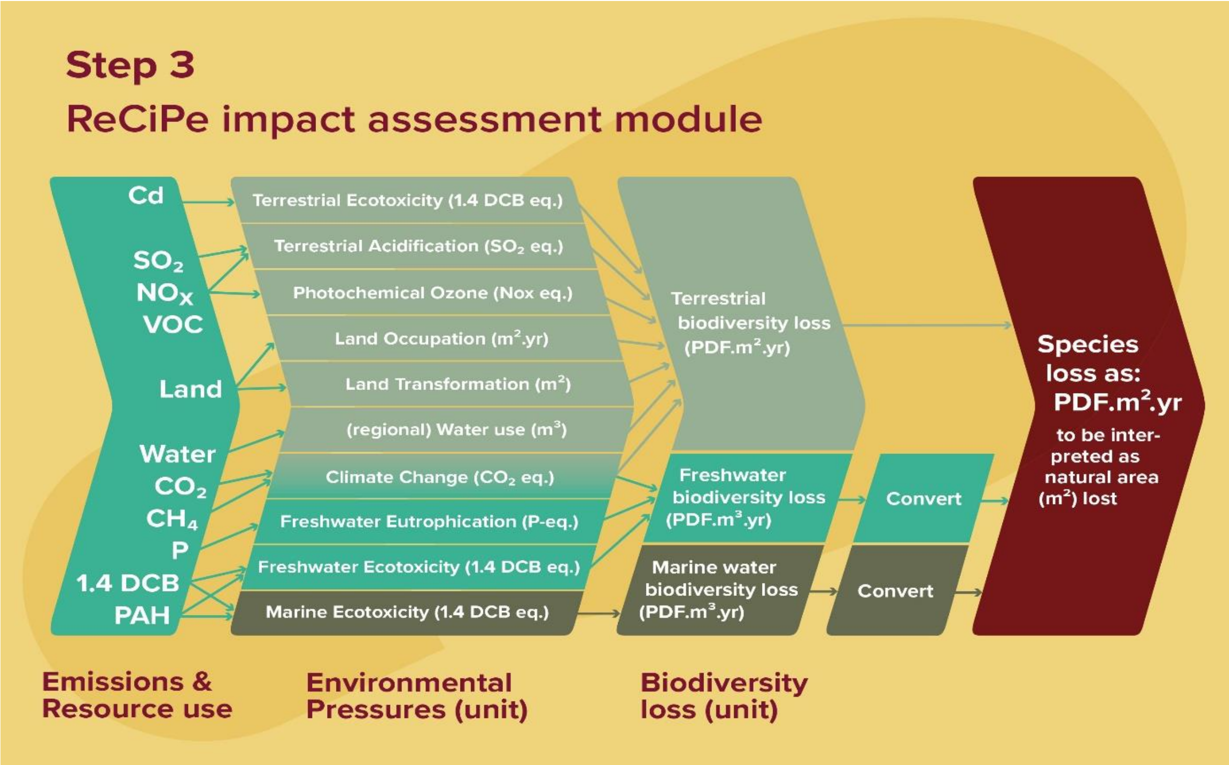

Figure 4. Schematic overview of the environmental mechanisms in the ReCiPe method and their relation to the endpoint. Adapted from: 'ReCiPe 2016. A harmonized life cycle impact assessment method at midpoint and endpoint level', RIVM[18]

A key characteristic of the ReCiPe 2016 method is that it translates 17 impact categories into three so called endpoints: Human Health, Ecosystems and Resources. For the BFFI, we have excluded the impacts on human health and resources, because the focus is on biodiversity. Figure 3 provides an overview of how 10 impact categories are linked to biodiversity impacts, expressed as **PDF.m².yr.** For a detailed description of how all these impacts influence biodiversity we refer to the ReCiPe 2016 report[18] and the underlying peer reviewed scientific articles.

[18] https://www.rivm.nl/bibliotheek/rapporten/2016-0104.html

The unit of the 'ecosystem damage' is defined as '**PDF.m².yr**' for land-based ecosystems and '**PDF.m³.yr**' for water-based ecosystems. The term PDF refers to 'Potentially Disappeared Fraction of species'. This means the percentage or fraction of species that are no longer found, due to a man-made impact of some kind[19]. This percentage is calculated with the surface area or water volume, and the time[20]. For impacts in ecosystems in fresh water and marine (salt) water, we cannot use the surface area, but we need to use a volume. This explains the unit PDF.m^3.yr. To reconcile these two units to one unit, the PDF units are divided by the average species density on one square meter land, one cubic meter fresh water and one cubic meter marine water.

The result of this calculation in step 3 is a number with the unit called '**species.year**'[21] The unit 'species.year' is the official unit of ReCiPe, but for our purpose it is not very meaningful. In the BFFI, we convert all impacts on water back to the unit for land-based system, so the unit is thus PDF.m^2.yr. If we get a result of 100 PDF.m^2.year, this means we may have a complete loss (PDF=100%) of biodiversity on an area of 100 m^2 during a year, or a loss of 10% of the species on an area of 10m^2 over a period of 100 years. **PDF, area size, and time are interchangeable**. To make the presentation of the result even simpler, we will set the time to one year, because the scope of the footprint is annual. We set the PDF to 100%. This allows us to express the result simply as 'm^2 lost ecosystems during a year'.

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[19] We typically refer to vascular plants on land and lower organisms in water and sometimes other lower organisms. These lower organisms are typically at the beginning of the food chain, and if something goes wrong there, it will have impact on the higher organisms. Modelling the disappearance of higher organisms is much more difficult, as there are many factors that determine their fate, including hunting, poaching etc.

[20] Example: If a farmer wants to produce 1 kg of corn, it needs a certain area, during a year (or half a year if there are two harvests). During that time the number of species on the corn field is reduced. This means the damage has three elements, a potentially disappeared fraction, a surface area in m2 and a time element, expressed in years. For a CO2 emission this somewhat less intuitive, but one can imagine that a kg will not stay for ever in the atmosphere, which explains the time element. One kg can also not make a species disappear all over the world, so there is a limited reach, explaining the area part of the formula.

[21] The following data are used for species density on land per m2: 1.48E-8; Species density in Fresh water, per m3: 7.89E-10; Species density in Marine water per m3: 3.46E-12 Note that these species density figures are quite uncertain; only a small part of all species have been documented, so it is not too well known how many species there are. This is especially true in oceans; only the upper 200 meter have been taken into account, as below this, very little is known. By using the PDF score for land, we eliminate this uncertainty for terrestrial ecosystems, while we have an extra uncertainty for aquatic systems, as these impacts undergo two conversions, one from PDF.m3.yr to species.year and one from species.year to PDF.m2.yr. Most global biodiversity assessment tend to focus on the damage on terrestrial ecosystems, so we think it is better to have these right and include the aquatic systems with more uncertainty.

Step 4: Interpret the results and take action

As with all footprint calculations, there are limitations to the BFFI method. An important limitation in the current calculations is the lack of specificity, and especially the difficulty to take specific investment criteria into account. For instance, when we calculate the impacts of investing in a paper mill, the database used only contains data on the average paper mill in a specific country. However, financial institutions usually do not invest in an average paper mill, but for example only in paper mills that source wood from FSC certified forests. The positive effect of this requirement is not visible in the calculations, which creates a limitation for specific investments. Ultimately, it does mean that the results of the footprint can be seen as a conservative worst-case scenario. This limitation can however be overcome with more company- or product-specific primary data.

3.2 Specific calculations for various asset classes

There are many different types of financial assets, and different investors split assets up into different classes - as there is more than one way to slice a cake. Splitting up assets into different asset classes allows investors to invest in a diversified investment portfolio. Common asset classes are:

- Listed equity
- Mortgages
- Bonds
  - Sovereign bonds
  - Local government bonds
  - Green bonds
- Project finance
- Loans

As each asset class has their own particularities, specific calculation approaches are used for various asset classes. The following chapters briefly describe the various calculations approaches taken per asset class listed above, to reflect the characteristics of the financial product better. Other asset classes can also be assessed, the above serve as most common examples.

3.2.1 Listed equity

A financial institution can make investments in equities. An important issue is how we interpret the investments and how we link them to the economic sectors in the EXIOBASE Input Output database, as this is not always obvious. We take the example of Adidas and a simplified Adidas AG supply chain to illustrate the approach (Figure 4).

Adidas is known for producing sportswear, but it does not own any production facility. Adidas, like most multinationals, has outsourced most of its production. They work with around 700 independent factories from all over the world. These suppliers manufacture products in more than 50 countries. Some partners are directly contracted, and others are not. Therefore, is it so difficult even for Adidas themselves to get direct data on the environmental impact of their suppliers.

Adidas does own shops and a distribution system and can therefore be seen as a retail company, mostly involved in design and sales of footwear and apparel. This means that there is no production in scope 1 and 2. Most impact, however, is taking place in the beginning of the supply chain, so we model the environmental impact using background data.

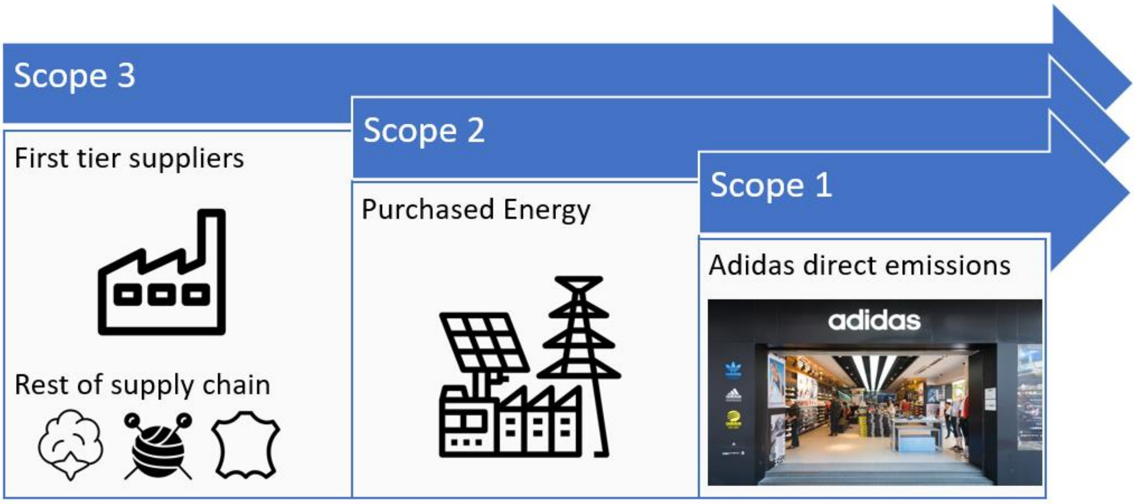

Figure 5. Simplified operational scope of Adidas AG

The financial institution has shares in Adidas of an approximate value of let's say €100 000 000. This accounted for about 0.15 % of Adidas total Market Capitalisation. To calculate the impact on biodiversity from the financial institutions' investment in Adidas, computations account for the share of the particular investments attributed to the company's activity and relative impact of different countries the company operates in.

Firstly, the share of the investments attributed to each company is calculated as the financial institution's investment divided by the company's or enterprise value in a given year. The data for the investment and market capitalization of each company are delivered by the financial institution or taken from statistics. Enterprise value is derived as of 31st of December of the year.

For each company, we built a model using EXIOBASE datasets, the linking matrix, and the fund information. The financed impact is calculated in the following way:

$$\sum \frac{Value\ of\ investment\ _{Company\ i}}{Enterprise\ Value\ _{Company\ i}} \times revenue\ _i \times share\ in\ country\ _y\ \times sector\ emissions\ and\ resource\ use$$

In case company specific reported carbon footprint data of sufficient quality is available, the carbon footprint values can be translated to the biodiversity footprint calculations to replace the default climate change impact on biodiversity.

3.2.2 Mortgages

For the asset class mortgages, we considered, for existing houses, that the impact is only caused by the occupation of the land and the energy expense arising from having a house occupied. We consider that each year a mortgage is continued, the occupation of the land, and the energy used in that year can be related to the mortgage. The transformation that may have occurred before the building was not considered, because we do not know whether such a conversion took place, and what the biodiversity value of the land was before it was converted.

The financed impact is calculated in the following way:

$$\sum \frac{Outstanding\ amount}{Property\ value\ at\ origination} \times Energy\ consumption \times Energy\ emissions\ and\ resource\ use$$

The subject of the mortgage assessment is the specific electricity and gas use for the houses for which the financial institution provides a mortgage. The impact from energy and gas use is modelled using the EXIOBASE datasets:

- Electricity Mix NL (or other location of the mortgage)
- Distribution of gaseous fuels trough mains

The default procedure with ReCiPe is used for the impact assessment. It is possible to add land use to consider the biodiversity impact of green roofs. Water consumption can also be added to the impact calculation of mortgages. The choice to include this depends on the extent to which a financial institution should be responsible for household water use.

The electricity consumption is modelled by dividing the total electricity usage (in kWh) per year of the mortgaged location and by the market value of the mortgage (in MEuro) to obtain the share of electricity consumption per MEuro mortgage. The natural gas usage is modelled by dividing the total gas consumption (in m3) per year of the mortgaged location, multiplied with the current (or average) gas price per m3, and divided with the market value of the mortgage (in MEuro). As the dataset "Distribution of gaseous fuels trough mains" is modelled in monetary values (MEuro2011), we adjust the input to include inflation. The result obtained mirrors the price of natural gas consumption per MEuro invested in 2022.

As a last step, both datasets, modelled per MEuro invested, are added, and computed with the BFFI, and result in a single value for biodiversity footprint (PDF.ha.yr) per MEuro investment in the specific mortgage.

This calculation can be performed for individual mortgages, or in one calculation for all mortgages in a portfolio. A set of mortgage portfolios, for instance private and corporate mortgages, can be calculated depending on the needs of the financial institution.

3.2.3 Bonds

Bonds are debt securities with a fixed income for the investor. Most common types are government bonds and corporate bonds. In sustainable investing, green bonds, or climate bonds are issued. This asset class is covered in paragraph 3.2.4 Investments in renewable energy.

Sovereign Bonds

The impact of government bonds in based on government spending, the government debt, and the size of the investment. The financed impact is calculated in the following way:

$$\sum \frac{Value\ of\ investment\ _{government\ bond\ i}}{Soevereign\ debt\ _{country\ i}} \times Emissions\ and\ resource\ use\ government\ spending$$

To allocate the investment of the financial institution in the asset class of sovereign bonds, the share of the country's debt attributable to the financial institution is assessed. For each country to which the sovereign bond is issued, the general gross debt is extracted from the Eurostat database. The investment into each country is then divided by the country's debt to account for the share of the financial institution in the country's borrowings. The resulting factor is then used to compute the impact of governments' bonds with EXIOBASE dataset 'Final consumption expenditure by government'.

This approach allows to account for a more accurate representation of the share of government's expenditures that the financial institution is responsible for and to stay consistent with the methodology used for equity investments (into individual companies).

Lastly, the biodiversity impact of the sovereign bond is calculated by running the activity data with the BFFI to obtain the biodiversity impact in PDF.ha.yr per MEuro invested.

Local governments

The impact from loans to local governments is based on their annual spending. For example, the budget and realization from the municipalities in the Netherlands are transparent and freely available at openspending.nl. We used the benchmark of the 44 biggest municipalities in the Netherlands to model the distribution of the expenditures of local government. We extracted the shares of each investment in the following sectors, linked to corresponding EXIOBASE datasets, and broke down the corresponding investments into each category (Table 1). For investments in specific municipalities, the specific realization from those municipalities can be used to model the economic activities. As the specific EXIOBASE datasets are based on the monetary unit of MEuro 2011, the input values are inflation adjusted.

The financed impact is calculated in the following way:

$$\sum Investment \times Goverment\ spending\ per\ sector\ \times\ Emissions\ and\ resource\ use\ per\ sector$$

Government spending per sector	EXIOBASE dataset	% of government spending
Governance and support	Public administration and defense; compulsory social security (NL)	26%
Safety	Public administration and defense; compulsory social security (NL)	3%
Traffic, transport, and water management	Other land transport (NL)	6%
Economy	Public administration and defense; compulsory social security (75) (NL)	2%
Education	Education (NL)	4%
Sports, culture, and recreation	Recreational, cultural and sporting activities (NL)	7%
Social domain	Health and social work (NL)	38%
Public health and environment	Health and social work (NL)	7%
Public housing, spatial planning, and urban renewal	Public administration and defense; compulsory social security (NL)	7%

Table 1: Investment Sectors and Corresponding EXIOBASE Datasets for Local Governments

3.2.4 Investments in renewable energy

Green Bonds

Green bonds can take many different forms. Many green bonds finance projects that support more sustainable sectors, such as renewable energy generation and energy efficiency, low-carbon mobility infrastructure, sustainable Agri- and aquaculture, water management, and more. Sometimes, green bonds also have a restoration-intention, hence aim at improving or restoring natural environment. Apart from potential benefits, green bonds can still cause negative impacts on the environment. The main negative impact from green energy investments for example is in the production of the materials for the generation on renewable energy (for instance windmills and photovoltaic panels).

Example: If we assume that the renewable electricity produced in a country replaces conventional energy production systems within that country, then the net-impact in hectares from renewable energy investments can be negative, meaning that the effect of these investments on biodiversity is positive[22]. Hence, depending on the conventional grid mix of the location, renewable energy investments could contribute to a net-positive-gain strategy. If the specific composition of the green bond is known, the exact impacts can be modelled. The more project-specific data is available, the more specific the results can be. Below you find a brief example for calculating the impacts of a green bond investing in wind energy, first with a default approach, followed by an example of more project-specific calculations. Further, we briefly explain approaches for various energy technologies.

Renewable energy green bonds - The default approach

By default, renewable energy projects are calculated using country specific data. The investment from the financial institution (in Euro) is translated to an expected electricity generation in MJ (or kWh). The first step is to calculate the expected installed capacity from an investment in wind energy. This is done by multiplying the value of the investment by the investment costs in Euro per kW. This value differs per country and per type of energy generation. It is based on the expected installed capacity per invested euro, the capacity factor per country and the expected annual electricity production per MEUR invested.

The biodiversity impact from investments in renewable energy is derived by calculating the impact of the expected electricity production from the generation source and subtracting the same amount of electricity from the average grid mix in the country where the renewable energy project is located. Taking the difference between the construction and the avoided average grid mix[23] gives us an insight into the impacts of the green bond investment.

[22] As electricity generation is changing, this benefit will disappear if all electricity comes from non-fossil sources.

[23] The term grid mix refers to the average supply mix of various types of energy production systems on an electricity grid. It can both refer to the physical grid mix (all power plants that produce energy in a country or in Europe), as well as to the mix of the company that sells the electricity to the consumer.

Wind energy

For wind Energy, for cases where the annual electricity generated by the project is not known, the investment from the financial institution (in Euro) has to be translated to an expected electricity generation in MJ (or kWh). The first step is to calculate the expected installed capacity from an investment in wind energy. This is done by multiplying the value of the investment by the investment costs in Euro per kW. This value differs per country and per type of wind park (onshore or offshore). The following table includes the expected installed capacity per invested euro, the capacity factor per country and the expected annual electricity production per MEUR invested.

Country	Costs onshore (2021 EUR/kW)[1]	Costs offshore (2021 EUR/kW)[1]	Capacity factor onshore1	Capacity factor offshore1	Annual Electricity Production (MJ) per MEUR invested (onshore)	Annual Electricity Production (MJ) per MEUR invested (offshore)
The Netherlands	1663*	2525	0.37	0.46	6941048	5745759
Germany	1765	3855	0.28	0.42	4950493	3436150
Belgium	1663*	3655	0.37	0.41	6941048	3537903
United Kingdom	2000	3152	0.41	0.48	6481350	4803128
Ireland	1663*	2861	0.37	0.48	6941048	5291229
France	1834	2861	0.36	0.48	6140100	5291229
Denmark	2054	2360	0.39	0.5	5988643	6681940
Europe average	1663*	2861	0.37	0.48	6941048	5291229

* For some countries no specific costs per kW were reported, therefore the average European value was taken

1. IRENA (2022), Renewable Power Generation Costs in 2021, International Renewable Energy Agency, Abu Dhabi.

Table 1: Overview of data for the calculation of the expected annual wind energy production per MEUR invested

Solar PV

For Solar PV, we follow the same procedure to quantify the expected annual energy production per invested euro. First, we translate the investment from the financial institution (in Euro) to an expected electricity generation in MJ (or kWh). We calculate the expected installed capacity from an investment in solar PV. This is done by multiplying the value of the investment by the investment costs in Euro per kW. This value differs per country. The following table includes the expected installed capacity per invested euro, the capacity factor per country and the expected annual electricity production per MEUR invested.

Country	Costs installed PV (2021 EUR/kW)[1]	Capacity factor PV1	Annual Electricity Production (MJ) per MEUR invested
The Netherlands	1054	0,172*	5147743
Belgium	855*	0,172*	6346763
Germany	715	0,172*	7586418
United Kingdom	874	0,172*	6204512
Ireland	855*	0,172*	6346763
France	833	0,172*	6510174
Denmark	855*	0,172*	6346763
Europe average	855*	0,172*	6346763

* For some countries no specific costs per kW were reported, therefore the average European value was taken

1. IRENA (2022), Renewable Power Generation Costs in 2021, International Renewable Energy Agency, Abu Dhabi.

Table 2: Overview of data for the calculation of the expected annual solar energy production per MEUR invested

Bio-energy

For bio-energy projects, only average European values were available. We used the average installation cost of € 4008 per MW and a capacity factor of 0.81 (IRENA 2012). In EXIOBASE, the dataset “Production of electricity by biomass and waste” is used. This is a very broad sector which includes all types of biomass and waste. Therefore, it will vary per project how well the datasets represent the impacts of a specific project.

Other renewable energy

For projects or organizations in the portfolio which do not describe the type of energy in which they invest, you can take the average intensity value (in m²/€) of all investments in renewable energy to calculate the number of hectares affected by the investment.

3.2.5 Loans to other financial institutions

Loans to other financial institutions are, amongst others, used to meet regulatory requirements. The impact of those loans is calculated based on the direct impact of the financial sector in the respective countries where the FI’s are based.

For loans to other financial institutions, the impact can be calculated using the operating income of the financial institution and the impact of the EXIOBASE dataset for *“Financial intermediation,* *except insurance and pension funding*" or "*Insurance and pension funding, except compulsory social security*" of the country where the head office of the financial institution is located. The total impact of the financial institution can then be divided by the total value of the assets under management to calculate the impact per euro on loan.

The financed impact is calculated in the following way:

$$\sum \frac{Value\ of\ investment\ _{FI}}{Balance\ sheet\ total\ _{FI}} \times operating\ income\ _{FI} \times sector\ emissions\ and\ resource\ use$$

4 Future development & references

4.1 Future development

We keep our methods up to date with the latest development in the field of sustainable finance and scientific progress biodiversity metrics. Therefore, we have a number of improvements in our roadmap.

Listed equity and corporate bonds

We can currently use MSCI, Refinitiv WorldScope, FactSet and Iceberg Datalab, and manually collected revenue data as input in our calculations. This flexibility allows us to work with any data provider. This allowed us to calculate the footprints of over 10 000 listed companies. We also include company specific carbon footprint data where available. Our method is open to use other data sources as well, so we will continue to collect or cooperate with other parties to widen our coverage and deepen our analysis by including more company specific data. The footprints will be offered as ready to use BFFI results database.

Other asset classes

We will update our methodology for government bonds, mortgages, and specific investments with positive biodiversity impact.

Background data

As EXIOBASE v3.4 is becoming increasingly outdated, we will update to EXIOBASE v4, increasing sector granularity to 600 and temporal correlation to 2016.

Downstream impacts

For most asset classes, downstream impacts are not included in most asset classes. The goal is to include sector average downstream impacts for all sectors in EXIOBASE.

Impact assessment method

We are currently using the ReCiPe2016 impact assessment method. We aim to update the climate model to the latest IPCC method and include the more regionalized Chaudhary land use method.

On the long term, we will look at the need to add an MSA metric to our analysis and adapt to the Global Guidance for Life Cycle Impact Assessment (GLAM) recommendation on impact assessment method. Furthermore, we will contribute to the discussions on including biodiversity in the EU Product Environmental Footprint initiative.

Dependencies on Ecosystem Services

Following our work with the UNEP WCMC (see ENCORE reference in section 4.2), we expand our work on dependencies.

Applications, links with other initiatives and legislation

We aim to improve the guidance for applications of the BFFI. This includes how to use the BFFI for reporting in line with the Taskforce Nature Related Financial Disclosure (TNFD) and how to use biodiversity footprinting for target setting according to the Science Based Targets for Nature (SBTN).

4.2 References

The two main building blocks of the BFFI are the background database, EXIOBASE, and the impact assessment method ReCiPe. The following documentation is available:

EXIOBASE: https://www.exiobase.eu/
A special issue of Journal of Industrial Ecology (Volume 22, Issue 3) describes the build process and some use cases of EXIOBASE 3.

ReCiPe 2016: https://www.rivm.nl/bibliotheek/rapporten/2016-0104.pdf
Huijbregts, M.A.J., Steinmann, Z.J.N., Elshout, P.M.F. *et al.* ReCiPe2016: a harmonised life cycle impact assessment method at midpoint and endpoint level. *Int J Life Cycle Assess* **22**, 138–147 (2017). https://doi.org/10.1007/s11367-016-1246-y

ENCORE: https://encore.naturalcapital.finance/en
The BFFI can report dependencies on ecosystem services using the ENCORE database. The pilot project with example calculations can be found here:
Kan, D.M. Patel, R. Leach, K. Bekker, S. Dawkins, K. Broer, W. (2021) Biodiversity impact and ecosystem service dependencies. Integration of dependencies using the BFFI and ENCORE. 48 pp. PRé Sustainability, CREM, UNEP-WCMC, Ministry of Agriculture, Nature and Food Quality.

Natural Capital Finance Alliance (Global Canopy, UNEP FI, and UNEP-WCMC) (2022). ENCORE: Exploring Natural Capital Opportunities, Risks and Exposure. Cambridge, UK: the Natural Capital Finance Alliance. DOI: https://doi.org/10.34892/dz3x-y059.

The BFFI has been included in several reports on tools to assess biodiversity impacts of investments:

WWF 2021:
https://wwfint.awsassets.panda.org/downloads/wwf_assessing_portfolio_impacts_final.pdf
Hilton, S. and Lee, JM J. Assessing Portfolio Impacts - Tools to Measure Biodiversity and SDG Footprints of Financial Portfolios. Gland, Switzerland: WWF, 2021.

Finance for Biodiversity Foundation:
https://www.financeforbiodiversity.org/wp-content/uploads/Finance-for-Biodiversity_Guide-on-biodiversity-measurement-approaches_2nd-edition.pdf
Iris Hertog, Anne-Marie Bor, Anita de Horde, (2022) Finance for Biodiversity Guide on biodiversity measurement approaches (2nd). EU Business@Biodiversity Platform, Finance@Biodiversity Community.